IPAI: Innovation and Practical Ability Improvement Method Based on Data Analysis of Science and Technology Competition

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Abstract. To cultivate engineering and technical talents with innovation spirit and practical capability that meet the urgent social needs, we establish and solve the principal component analysis (PCA) model of the factors affecting the performance of the science and technology innovation competition, and obtain the influencing factors with lower principal components and further improve them. Meanwhile, the innovation and practical ability improvement (IPAI) method is proposed. It is mainly composed of basic capability improvement method, system design capability improvement method, and comprehensive capability improvement method. Firstly, we improve the circuit design ability and embedded programming ability through the basic ability improvement method. Secondly, the system design ability improvement method is used to enhance innovative thinking and comprehensive design ability. Finally, we use the comprehensive ability improvement method to cultivate innovation ability, practical ability, psychological resilience, teamwork ability, and practical problem analysis and solving ability. We put the IPAI method into practical application, in terms of talent training, social and economic benefits, positive results have been achieved.

Keywords: principal component analysis · subject competition · basic design ability · system design ability · comprehensive ability

1 Introduction

At present, the new generations of information technology and manufacturing industry are deeply integrated in the world. Under this change, it is urgent to cultivate a large number of emerging engineering and technical talents with innovation and practical ability. As the most important place for talent training, universities need to explore and establish a new model of innovative engineering and technical talents training, and then they can

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continuously improve the engineering technology training system for talent training, so as to enhance the innovation spirit and practical ability of these brains and meet the needs of the new generation of industrial development [3, 7]. Cultivating high-level engineering and technical talents requires rich practical teaching experience. In higher education, subject competition is an important link in practical teaching, and it is also an effective approach to foster innovative spirit and engineering technology capabilities. Meanwhile, actively organizing students to participate in subject competitions can be helpful for improving students' ability in competition, innovation, and practice. It is of great significance for universities to cultivate emerging engineering and technical talents with innovative and practical ability [1, 2, 4, 6].

Therefore, in the 57 competitions recognized by the China Association of Higher Education, this paper makes a thorough analysis of the China College Students' "Internet +" Innovation and Entrepreneurship Competition, the National Undergraduate Electronics Design Contest [5], and the "Blue Bridge Cup" National Software and Information Technology Professional Talent Competition.

According to the historical data of each competition, we establish and solve the principal component analysis (PCA) model of the factors affecting the performance of the science and technology innovation competition, and obtain the influencing factors with lower principal components and further improve them. Meanwhile, we propose a method for improving students' innovation spirit and practical ability based on electronic information subject competitions (IPAI). Firstly, through a thorough analysis of the common technical points of various competitions, it is concluded that analog circuit design and embedded programming are the basic capabilities, and the design covers comprehensive analog circuit problems and embedded programming topics as the course content, with the purpose of improving the basic design ability. Secondly, in order to develop the system design ability, the comprehensive topics with the combination of software and hardware are used as the design content, and the innovative thinking and system design ability are improved in an all-round way. Finally, through the comprehensive ability improvement method, we organize students to participate in various discipline competitions and cultivate students' innovation ability, practical ability, psychological resilience, teamwork ability, and practical problem analysis and solving ability.

2 PCA Model

In order to further improve the competition results of undergraduates and cultivate more and better engineering and technical talents, we use the principal component analysis model to analyze the data of electronic discipline competitions over the years and then obtain the factors that need to be improved. The real-time steps of the principal component analysis model are as follows:

Step 1: Standardization data.

We make n observations of P parameters that affect the competition performance and obtain the data observation matrix:

$$X = (x_{ij})_{n\times p} = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1p} \\ x_{21} & x_{22} & \ldots & x_{2p} \\ \ldots & \ldots & & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{np} \end{bmatrix} = (x_1, x_2, \ldots x_p)^T \tag{1}$$

Normalize each element in X by Eq. (2) to get the standardized matrix Z.

$$\tilde{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}(i = 1, 2, \ldots, n; j = 1, 2, \ldots, p) \tag{2}$$

where,

$$\bar{x}_j = \sum_{i=1}^{n} x_{ij}, s_j^2 = \frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{n-1}$$

Step 2: build a coefficient correlation matrix.

Find the correlation coefficient matrix for Z.

$$R = \frac{1}{n-1} Z^T Z \tag{3}$$

Step 3: Calculate eigenvalues, eigenvectors, and cumulative contribution rate of principal components.

We solve the characteristic Eq. (4) of the R matrix in Eq. (3), get p eigenvalues of λ_j, and determine the value of m based on Eq. (5),

$$\left|R - \lambda I_p\right| = 0 \tag{4}$$

$$\frac{\sum_{j=1}^{m} \lambda_j}{\sum_{j=1}^{p} \lambda_j} \geq 0.85 \tag{5}$$

Solve $Rb = \lambda_j b, j = 1, 2, \ldots, m$ to get the unit eigenvector b_j^0.

Step 4: Determine the principal components.

We calculate $U_{ij} = z_i^T b_j^0, j = 1, 2, \ldots, m$, and get $U_1, U_2, \ldots U_p$ principal components.

Step 5: Calculate the composite aliquot.

The weighted summation of m principal components is performed to calculate the final evaluation value.

The smaller the score, the more improvement the indicator needs.

The main factors such as the number of participants, publicity, course training, the number of instructors, and the reward system have an impact on the performance of

Table 1. The scores and rankings of each science and technology competition

Evaluation index	Specific indicators	numbers
Number of students	The number of people who participate in the competition each year	≤ 200
Publicity	Total number of people advertised	≤1000
Courses	Number of related courses	≤15
Number of teachers	Number of teachers guiding the competition	≤ 20
Rewards	Extra-curricular credits earned by students per competition	1 ~ 2

Table 2. The scores and rankings of each science and technology competition

Science and technology competition		Number of students	Publicity	Courses	Number of teachers	Rewards
"Internet+"	Scores	1.3312	0.8735	-0.1447	0.2198	-0.4417
	Ranking	1	2	4	3	5
"Challenge Cup"	Scores	0.6718	3.6161	-1.9891	0.2979	0.01123
	Ranking	2	1	5	3	4
The national undergraduate electronics design contest	Scores	0.3114	0.8917	0.1011	2.2214	-0.2810
	Ranking	3	2	4	1	5
"Blue Bridge Cup"	Scores	1.9844	0.4098	-1.3321	0.5719	-0.1104
	Ranking	1	3	5	2	4

the science and technology innovation competition, see Table 1 for the relevant data. According to the principal component analysis model, the principal component analysis of each subject competition in our college is carried out, and the analysis results are shown in Table 2.

As shown in Table 2, in the electronic discipline competitions that our school participated in, the courses and reward factors were between 4 and 5.

In order to further improve our school's academic competition performance, we can achieve this by increasing curriculum construction and rewards. In terms of awards, this year our school has introduced additional scholarship awards in addition to credit awards. In terms of curriculum construction, we have proposed an IPAI method to specifically improve students' ability to compete in science and innovation, which complements the correct deficiency of relevant courses in our school.

3 IPAI Method

This section introduces the IPAI method in detail. Firstly, the basic practical ability improvement method is described. Secondly, the system design ability improvement method is explained. Finally, the comprehensive ability improvement method is used to guide students to participate in the discipline competition. The method flow is shown in Fig. 1.

3.1 Methods of Improving Basic Abilities

This section introduces the basic ability improvement method. Analog circuit design is carried out first to improve circuit design ability, and then we utilize embedded programs to develop programming ability.

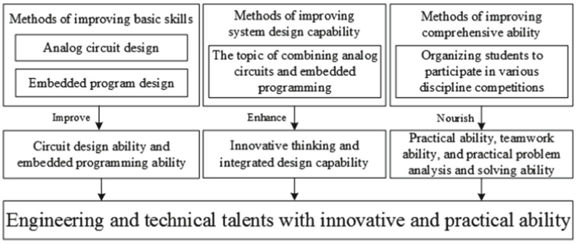

Fig. 1. IPAI method

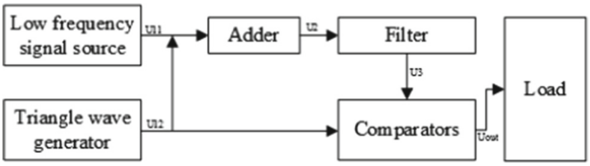

Fig. 2. Signal Flow for Analog Circuit Design

3.1.1 Analog Circuit Design

As the basis of circuit design, analog circuits are mainly used to generate and process signals. The main technical modules of analog circuits include amplifier circuits, signal operations, oscillation circuits, modulation and demodulation circuits, and power supplies, and mastering all kinds of basic circuits in an all-round way can provide a strong guarantee for the project's signal acquisition digitization and the generation of various wave forms. Fortunately, in the comprehensive evaluation question of the in the 2011 National Undergraduate Electronic Design Competition, it covers the design requirements of most of the main technical modules of analog circuits. Therefore, we optimize and improve this question as the training content of analog circuit design. The signal flow is shown in the Fig. 2, and the specific design requirements are as follows.

Firstly, we use the low-frequency signal source to generate $U_{11} = 0.1 \sin 2\pi f_0 t(v)$ $f_0 = 500$ KHz sine wave signal. Secondly, the self-excited oscillation circuit is utilized to generate $U_{12} = 2$ KHz, and the peak value is plus or minus 2 V triangular wave signal. Thirdly, we design the adding circuit to realize the adder output signal $U_2 = 10U_{11} + U_{12}$. Fourthly, the frequency selection filter circuit is used to remove the U12 component, $U_3 = 10U_{11}$ is obtained, and U_3 is amplified to plus or minus 4.5 V. Finally, U_{12} and U_3 are compared and output. When the output signal U_{out} is loaded on a 2k load, the amplitude plus or minus 1V. Among them, all signal conversions can only be completed by a LM324 chip, and the power supply can only use two single power supplies of 12 V and 5 V.

3.1.2 Embedded Program Design

In electronic discipline competitions, embedded systems are usually used to achieve analog-to-digital conversion, real-time data acquisition, human-computer interaction, logic control, storage and data transmission, etc. Fortunately, as shown in Fig. 3, most

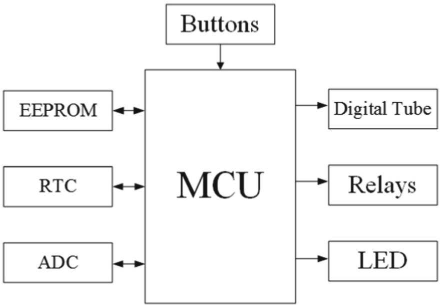

Fig. 3. Basic system block

of the above functional requirements are involved in the design and development of single-chip microcomputer in the fourth Blue Bridge Cup competition. On the basis of functions, the requirements for multi-computer communication and wireless data transmission increase, and the embedded programming ability is trained in an all-round way. The specific requirements are as follows.

Completing a set of "simulated intelligent watering system", as shown in Fig. 4, the system is mainly composed of application layer, data transfer layer, and control layer. The application layer is mainly used for human-computer interaction. It controls the watering state and displays the real-time data of each sensor through the APP and PC. This part does not need to be designed and produced, and the ready-made modules are directly used. The data transfer layer mainly realizes the upload and delivery of real-time data and commands and temporarily stores all data and control commands through the EEPROM to ensure that the current state can be saved when the power is turned off. Figure 5 is the control layer unit module, each module can realize environmental data acquisition and watering state control, and each control unit module can be expanded through the MAX485 bus.

3.2 Methods of Improving System Design Capabilities

This section uses a combination of analog circuits and embedded programming to improve system design capabilities. Since the front end of the 2019 National Undergraduate Electronic Design Contest titled "Line Load and Fault Detection Device" needs to design analog circuits for data collection, the back end needs to be embedded. It is very suitable for training the system design ability, so we improve this method as a method to improve the system design ability. The specific requirements of the topic are described as follows.

Figure 6 is the system block diagram of the fault detection device. The detection device is only connected to the two tested wires A and B through two terminals. The C wire is the short-circuit point. The distance between this position and the terminal is X. A set of faults is designed. The detection system meets the following requirements.

When there is a short circuit between the two wires A and B, that is, the two points A and B at the C position are connected, the X value can be intelligently measured and displayed stably, and the error is less than 1 cm. Introducing simulated environmental

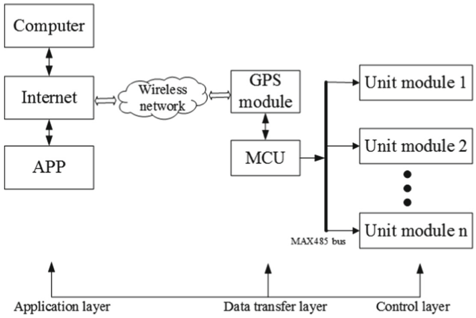

Fig. 4. System block

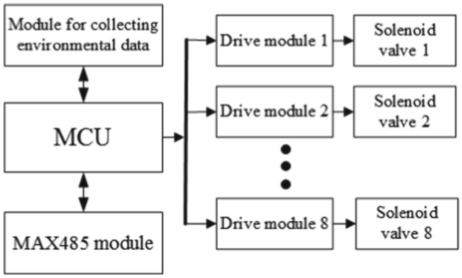

Fig. 5. Function of the control unit

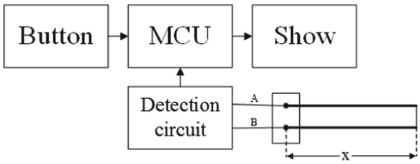

Fig. 6. System block of the detection device

noise (frequency: 100 Hz–1 kHz, peak-to-peak value: 5 V, average value: 0V) at the access end of the A wire, short-circuit the A and B wires at the C position and intelligently measuring the X value and displaying it stably, the error is less than 1cm. We provide the inspection circuit block diagram and related circuits as shown in Fig. 7. On this basis, students can improve and innovate by themselves and design and manufacture inspection devices that meet the requirements.

3.3 Methods of Improving Comprehensive Ability

Comprehensive ability can be improved by organizing students to participate in various subject competitions. At present, subject competitions can be divided into two types: self-propelled proposition and open-ended proposition. Autonomous proposition is unified by the organizing committee, and participating students complete all functions

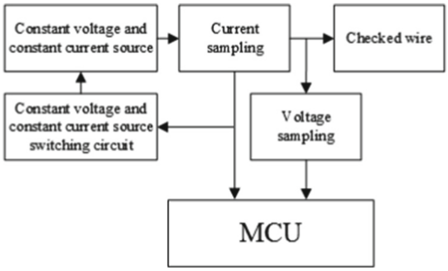

Fig. 7. Check circuit block

according to the requirements of the competition. Such questions are usually combined with the research hotspots and difficulties of cutting-edge technology, that is, to examine the basic design ability of the contestants and the learning ability of cutting-edge hot technology. For example, the 2019 National Undergraduate Electronic Design Contest A (dynamic wireless charging system for electric cars) combines cutting-edge wireless power transmission technology with electric cars to complete specific tasks. The open-ended propositions are mainly selected by the participating teams themselves, which mainly reflects the practical value of the selected questions. For example, China "Internet +" College Students Innovation and Entrepreneurship Competition, "Challenge Cup" National College Student' Extracurricular Academic Science and Technology Works Competition, etc. The independent proposition focuses on examining the technical mastery of the participating students. The participating students complete the competition questions according to the indicators. The more questions they can address, the higher the score. The open-ended proposition mainly examines the ability to solve practical problems and cultivate the ability of innovation and entrepreneurship.

According to the characteristics of independent propositions and open-ended propositions, the students' accumulation of basic ability training, and system design ability training and mastery of key technologies, students are selected to participate in the competition, and students' innovation ability, psychological resilience, teamwork ability, and practical problem analysis and solving ability and practical ability are improved through fierce competition.

4 Applications

We put the IPAI method into practical application. After the implementation of the basic ability improvement method and the system ability improvement method in the IPAI in the form of courses, the students' comprehensive design ability and ability to solve practical problems have been greatly enhanced. It has dramatic application effects in talent cultivation, social benefits and economic benefits.

4.1 Talent Cultivation

In terms of talent training, we actively organize students to participate in various discipline competitions, as shown in Fig. 8.

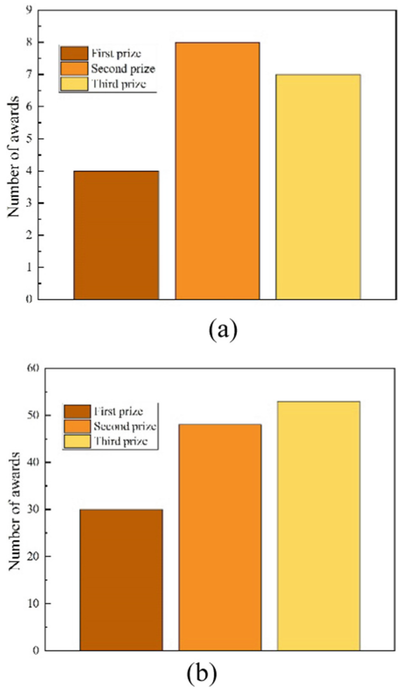

Fig. 8. Awards. a. National award, b. Provincial award

In the past five years, students have been selected to participate in the National Undergraduate Electronics Design Contest, The China College Students' "Internet +" Innovation, the "Challenge Cup", the "Blue Bridge Cup" National Software and Information Technology Professional Talent Competition, and the National College Student Engineering Training Comprehensive Ability Competition, etc. We won 4 national first prizes, 8 national second prizes, 7 national third prizes, 30 provincial first prizes, 48 provincial second prizes, and 53 provincial third prizes.

4.2 Social Benefits

We organized students to engineer the embedded design teaching cases, and they designed a "smart watering system" used in the experimental field of Huaxi Primary School.

In terms of environmental perception, the system can realize real-time collection and display of environmental temperature, humidity, light intensity and atmospheric pressure, and at the same time, it can set environmental data thresholds to alarm.

In terms of intelligent control, the system can control any watering valve through APP or PC and also set intelligent watering thresholds according to environmental perception data. When the environmental data reaches the set value, the experimental field will be irrigated automatically. The watering effect is shown in Fig. 9.

Fig. 9. Smart watering system

At present, the system has been in normal use for two years, and the system is running stably, solving the practical problem of long-term artificial watering of experimental fields in Huaxi Primary School and achieving considerable social benefits.

4.3 Economic Benefits

We cooperated with relevant energy companies to guide students to design and develop a set of "Intelligent Control System for Methyl Fuel Tanks", and the prototype is shown in Fig. 10. The system is divided into two parts: fuel tank control system and server management system.

The fuel tank control system can realize accurate and stable swipe card deduction, real-time temperature collection of the tank and threshold alarm, real-time leakage detection and alarm, real-time monitoring of the fuel quantity in the tank, etc. Data and abnormal alarm status are uploaded to the management system through GPRS network.

The management system has the highest authority and can display the temperature, leakage inspection, fuel tank status, user balance and abnormal alarm status of all fuel tanks put on the market in real time, and it can also modify the fuel tank status and abnormal alarm status.

At present, we have deployed the management system and produced 10 fuel tank intelligent control systems, which have been running stably for one year. The system solves the problem of intelligent control of restaurants using green fuel for cooking and achieves substantial economic benefits.

5 Copyright Form

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Fig. 10. Intelligent control system for methyl fuel tanks

6 Conclusion

To efficiently cultivate engineering and technical talents with innovation and practical ability, we established and solved the PCA model of the factors affecting the performance of the science and technology innovation competition, and obtain the influencing factors with lower principal components and further improve them by looking for the common basic technical points of each competition and conducting a thorough analysis of the basic technical points. Meanwhile, a new innovation and practical ability of students based on electronic information discipline competitions was proposed. Firstly, through the basic ability improvement method, we used analog circuit design and embedded programming to improve the basic practical ability. Secondly, we took the comprehensive topics with analog circuit design and embedded programming as the implementation content of the system ability improvement method, so as to improve students innovative thinking and comprehensive design capabilities. Finally, the comprehensive ability improvement method was adopted to guide students to participate in various discipline competitions, to cultivate innovation ability, practical ability, psychological quality, teamwork ability, and practical problem analysis and solving ability. We put the IPAI method into practical application, in terms of talent training, students were guided to participate in the subject competition, and they won 4 national first prizes, 8 national second prizes, 7 national third prizes, 30 provincial first prizes, 48 provincial second prizes, and 53 third prizes. In terms of social and economic benefits desired results have also been achieved.

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